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THE PATENTS ACT, 1970

It is hereby certified that annexed hereto is a true copy of Provisional and Complete Specification of the extract of Patent Application No. 059/MAS/2003 dated 20/01/2003 by Mr. R.Natarajan, # 201, "B" Block, SNS Arcade, Airport Road, Bangalore – 560 017, Karnataka, India.

.....In witness thereof

I have hereunto set my hand

Dated this the 16th day of February 2004

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FORM 2

THE PATENTS ACT, 1970
(39 of 1970)

5 PROVISIONAL / COMPLETE SPECIFICATION
(See section 10)

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A SYSTEM FOR PRODUCTION OF HYDROGEN WITH METAL HYDRIDE AND A METHOD

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The following specification particularly describes the nature of the invention and the manner in which it is to be performed.

A SYSTEM FOR PRODUCTION OF HYDROGEN WITH METAL HYDRIDE AND A METHOD

Field of invention

The present invention relates to a system to produce, store and dispense hydrogen gas by metal hydride encapsulation. The present invention further relates to a method for the storage and dispensation of Hydrogen gas by using said system.

Background and prior art

Hydrogen is stored conventionally as a gas or liquid. Hydrogen, due to its very low density, it is stored at very high pressures (more than 3000 psi) or as liquid hydrogen at a very low temperature of -253°C. To increase the storage density of hydrogen the application of metal hydride is adopted as an alternative method. The alkali metals and alkaline earth metals and also some of their hydrides and mixed metal hydrides are also used to generate Hydrogen on reaction with water. Sodium Hydride is an inexpensive metal hydride that is produced in bulk and hence generally preferred for the storage of hydrogen.

The following are the some of the advantages of storing hydrogen in metal hydrides: eliminates high pressure and cryogenic temperature storage, eliminates carbon emission observed in reforming of Methane and Methanol, production of the desired quantity of hydrogen only when required, and recycling of metal hydroxide to produce metal hydride.

The hydrogen from metal hydride is produced either by heating metal hydride to above 400°C or by reacting the metal hydride with water.

In heating process, the metal hydrides are extruded as rods, and are decomposed by heating them by means of electrical heaters or flue gas. The temperature for the decomposition is usually at about 400°C. The hydrogen is absorbed over the alkaline metal at high pressure and temperature.



The other alternate method of producing hydrogen is by reacting the metal hydride with water.

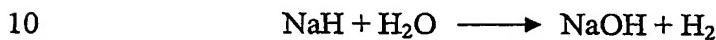


In the case of reaction by decomposition the amount of hydrogen produced is about 50% less when compared with the reaction of metal hydride with water.

Metal hydride decomposition system in automobiles

The requirement of pure hydrogen being a fundamental requirement in fuel cells or IC engines, the metal hydride rods have to be indirectly heated either by an electrical heater or by a flue gas. A separate energy source has to be provided for heating the metal hydrides, resulting in the occupation of more space in the automobile. Another limitation in the process is that factors pertaining to the production and absorption of Hydrogen vary during each recycling, since the metal hydride lattice starts cracking.

In a conventional hydrogen production system as depicted in Fig 1 of the accompanied diagrams, wherein the reactor adopts the following reaction in a reactor:



In this process, wherein the sodium hydride in the form of a ball having lesser density than water floats up and the unbroken plastic balls (1.3) are cut into two pieces at the topside of the reactor (1.6) by means of ramming devices (1.5) to enable the sodium hydride to react with water to produce hydrogen. The broken (1.2) pieces float in the upper region of the reaction chamber (1.6). However, the limitation of this process is that if the metal hydride thus used is heavier than water, in such an event a separate reactor is required for high density metal hydrides. An alkali storage device (1.4) is disposed to collect alkali as a byproduct. In the above-stated process, the metal hydrides are first formed into a spherical ball of about ping pong ball size and coated with flexible polyethylene jacket made of the following polymeric materials, polyethylene, polypropylene, Kraton, SBR, Noryl, Peek etc. In the above-stated conventional process hydrogen storage device (1.1) is different from the reaction chamber (1.6).

Limitations encountered in the conventional water treatment processes include in an upside down reactor system, dispensing of the metal hydride ball cannot be adopted, if the metal hydride balls are heavier than water, mixed metal hydrides like NaAlH that are adopted in the conventional processes are not readily available. It is also expensive to manufacture NaAlH exclusively for metal hydride project to generate Hydrogen. Flexible polyethylene balls that are used to store metal hydrides, conventionally, do not open out but only get crushed, which may result in the malfunctioning of the dispensing system. Further, a separate hydrogen storage tank, that is adopted in reactor system, along with dispensing unit, results in duplication of safety and control systems in addition to the addition of other components.

Accordingly, in view of the above limitations, in the present invention, spherical ball flow dynamics and disintegration of low density materials have been studied. During the studies, it was observed that the conventional flexible plastic balls can be opened only when they are sliced into two pieces with sharp chisel like object. It is also 5 further observed that when the brittle plastic balls are used for storing the metal hydrides, they disintegrate into small and tiny pieces, on impact with objects having blunt surfaces.

Objects of the present invention

Therefore, the primary object of the present invention is to provide a system that 10 is unified and modular for the production, storage and dispensation of hydrogen gas.

An object of the present invention is also to provide a system that can handle metal hydrides lighter and heavier than water for the production of hydrogen.

Another object of the present invention is to provide a system that can serve both as a hydrogen dispenser and a storage unit in the form of a single system.

15 Yet another object of the present invention is to provide a system with metal hydride storage the capacity of which can be easily increased by attaching additional storage modules to enable automatic and continuous supply of hydrogen at a required pressure and flow rate.

It is also an object of the present invention to provide an encapsulated metal 20 hydride with a flexible and brittle polymeric shell for hydrogen production.

Yet another object of the present invention is to provide a hydrogen gas which is about 99.9 % purity.

Still another object of the present invention is to provide a method for production, storage and dispensation of hydrogen by using said system.

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Summary of the invention

The present invention provides a system for production, storage and dispensation of Hydrogen gas by metal hydride encapsulation. The present invention further provides a method for the production, storage and dispensation of Hydrogen gas 30 by said system.

Brief description of the diagrams

Fig 1 depicts a conventional hydrogen production system.

Fig 2 is hydrogen production, storage and dispensation system of the present invention.

Fig 3 is a hydrogen regulator interface of the system of the present invention.

Fig 4 is cross section view of the manifold connectivity of cylinders for an enhanced hydrogen supply

Fig 5 a view of the container with baffles for regulating the encapsulated metal hydrides.
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Detailed description of the present invention

The preferred embodiments of the present invention are explained now with reference to the accompanied diagrams. Initially, referring to Fig 2, wherein a system of
10 the present invention for the production, storage and dispensation of hydrogen gas is disclosed. A plurality of sealed and replaceable metallic cylinders (7a) mounted vertically on a platform by means of bolts. A hollow and dome shaped lid (7b) is fixed on each of the cylinders (7a). A plurality of valves including pressure relief (13) to control the pressure levels inside the cylinder during operation. The description of the
15 components of cylinder as provided herein below would equally apply to all the cylinders of the system. A flush and fill valve (12) disposed on the lid (7b) of each of the cylinders, as means for flushing the cylinder with water during cleaning and to fill the cylinder with water (6) before the sealing of the cylinder (7a). A pressure control switch (9) to control the internal pressure levels of the cylinder (7a). A rupture
20 diaphragm (10) is fixed on the lid of the cylinder to release excess pressure and temperature levels. An outlet (1) disposed on the lid (7b) to provide an exit conduit for hydrogen gas produced in the process. Sealing means in the form of O-rings (14) are disposed between the top edge of the cylinder (7a) and bottom edge of the lid (7b). A pair of bolts (29) is used to seal the lid to the cylinder. A perforated mesh is mounted in
25 the meeting area of lid (7b) and the cylinder (7a) to provide a peripheral casing.

A rotatable and replaceable container (7) with funnel like inlet to store encapsulated metal hydride shells (2), said container (7) is fixed to the inner surface of the cylinder (7a), on both the sides, by supporting rings (16) with rollers (18) to provide a rotatable support to the container (7). Plurality of encapsulated metal hydride balls (2)
30 disposed in said container (7). Said balls (2) are fed into the container (7) through the funnel like inlet before it is sealed and mounted on the platform.

A slider base member (22) disposed at the bottom end of the cylinder (7) said slider (20) is fixed to the inner surface of the cylinder, on both the sides, by supporting

rings (23), said slider base member (22) acts as a bottom to the container (7), said slider base (22) having a passage (21), said passage in flow communication with a slider path (20) to transmit the encapsulated metal hydride (2) shells from the container (7) into the cylinder (7a).

5 A plurality of baffles (17 & 19) disposed both inside and outside periphery of said rotatable container (7a), said inner baffles (17) adapted to regulate and direct the flow of the encapsulated metal hydride shells (2) of the container (7) on to the slider path through said passage (21) of the slider base (20) and said outer baffles (19) adapted to rotate the container (7).

10 A pair of movable ramming means (11a) with a movable piston (11) and a hollow end (3) in flow communication with the cylinders (7a) extending plane perpendicular to the pair of cylinders (7a), where cylinders (7a) are symmetrically positioned. Ramming devices (11a) are used to connect a plurality of cylinders (7a) that are connected in series. Ramming means (11a) disposed at the bottom end of the slider 15 path, including a disintegrating site (25) and a hollow cavity (24) to receive the encapsulated metal hydride (2) from the slider and a movable piston (11) with blunt end for the disintegration and dispersion of broken shells and metal hydride into the cylinder (7a). A motion transmitting element (22a) mounted on the ramming means (11a) connected to outer baffles (19) to provide a corresponding rotatable action to the 20 container (7);

An outlet (27) at the bottom of the cylinder (7a) to release by products like NaOH, broken pieces of metal hydride, water. The control of the outlet (27) is done by means of a valve (28).

Now by referring to Fig 3, which depicts a top view of the system, involving a 25 series of cylinders (7a) by means of a ramming means (11a).

Fig 4 discloses a control panel (29) with time and change over switch (30 & 31) to control the selection of cylinder as desired. A hydrogen gas inlet (31) with "T" connection (36a, 36b, 36c) originating from various outlets (1) of the cylinders of the system as shown in Fig 1. The hydrogen flow rate is controlled by hydrogen pressure 30 regulator (33). The regulated hydrogen gas is sent out by means of valve (32) for further use.

Now by referring to Fig 5, which is a cross section of the container (7) showing internal and external baffles (17 & 19) along with spherical balls (2). A passage (21)

which is connected to slider path (not shown) to permit the passage of balls into the container.

A motor (4) mounted on the platform provides power to ramming means (11a) and for the rotation of the container (7a).

5 The preferred embodiments of the present invention are further explained as follows:

An embodiment of the present invention, wherein the said system can handle multiple containers to meet the demand of hydrogen productivity.

Another embodiment of the present invention, wherein said container is made of material selected from mild steel and stainless steel.

10 Yet another embodiment of the present invention, wherein the inner surface of the container is optionally coated with protective coating material selected from polyethylene, epoxy and polyester.

Still another embodiment of the present invention, wherein the conical container used for feeding and storing the encapsulated metal hydrides is disposed at an angle in 15 the range of 30-80° to get an uninterrupted and selected flow of encapsulated metal hydride materials to the disintegration site.

Further embodiment of the present invention, wherein said system handles both low and high density encapsulated metal hydride shells.

20 Further embodiment of the present invention, wherein the ramming means having a preferable hollow head on the sides to facilitate the holding of metal hydride shells during crushing.

Still another embodiment of the present invention, wherein the ramming means crushes the metal hydride shells into small and tiny debris that are collected at the bottom of the container for easy disposal and recycling.

25 Still another embodiment of the present invention, wherein the accumulation of disintegrated pieces of encapsulated metal shells facilitates in creating a space in the container itself for storing and dispensing of hydrogen.

Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells having shapes selected from spherical, cylindrical, rectangular and 30 square, spherical.

Further embodiment of the present invention, wherein the intervening gaps among the encapsulated metal hydride shells are utilized as an additional storage means for the hydrogen gas.

Still another embodiment of the present invention, wherein the encapsulation of metal hydrides is done using the polymeric material selected from polystyrene, poly methyl methacrylate (PMMA), PVC with less plasticizer, HDPE, brittle poly olefins, preferably polystyrene and PMMA.

5 Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells are sealed initially with solvents selected from chloroform, acetone, carbon tetra chloride and alcohol.

Still another embodiment of the present invention, wherein the encapsulated metal hydrides are further sealed with instant sealants.

10 Further embodiment of the present invention, wherein the hydraulic power means having a hydraulic seal is placed at the bottom of the system not only to prevent the leakage from the system but also to have a multi -container dispensing system.

Further embodiment of the present invention, wherein said system is adapted for manifold containers and the encapsulated metal hydride shells can be disintegrated simultaneously depending on the demand for hydrogen gas.

15 Yet another embodiment of the present invention, wherein said system is designed to enable the swapping of empty containers with filled containers with ease preventing the exposure to the chemicals.

20 Yet another embodiment of the present invention, wherein the hydrogen outlets are provided with non-return valves, pressure control valves and flow control valves.

In another embodiment of the present invention, the present invention also provides a method for the production, storage and dispensation of hydrogen by using the system of the present invention, said method comprising the steps of;

- (a) mounting the sealed cylinders on the platform filled with a proportionate quantity of water and a container with encapsulated metal hydrides,
- (b) directing the encapsulated metal hydride into the ramming means by means of baffles disposed in the container and crushing the desired quantities of encapsulated metal hydride shells to disintegrate into small pieces;
- (c) dispersing the metal hydride into the water;
- (d) reacting the metal hydride with water to produce hydrogen;
- (e) releasing the hydrogen through outlet means provided at the top of the cone and container; and

(f) collecting the disintegrated pieces and the byproducts at the bottom of the container.

An embodiment of the method wherein, the metal content for metal hydride is selected from Sodium, Boron, Lithium, Potassium and magnesium with an addition 5 aluminum powder, or any metal hydride capable of releasing hydrogen, preferably sodium hydride.

Another embodiment of the method wherein the plurality of cylinders disposed for simultaneous disintegration of enhanced number of encapsulated metal hydrides for the production of hydrogen gas.

10 Yet another embodiment of the method wherein the aluminum that is used is powder form is in the range of 5-50% to increase the density of the metal hydride and also to produce more hydrogen per unit volume by reacting with an alkali, preferably sodium.

15 Still another embodiment of the method wherein the byproducts consisting of NaOH and alumina.

Further embodiment of the method wherein the exothermic reaction condition of the process provides the desired temperature range for the formation alumina.

20 Yet another embodiment of the method wherein wherein the reaction of metal hydride takes place under controller pressure and temperature.

Still another embodiment of the present invention, wherein both low and high density encapsulated metal hydride shells can be used for production, storage and dispensation of hydrogen gas.

Further embodiment of the present invention, the exothermic reaction condition of the process provides the desired temperature range for the formation alumina.

25 Still another embodiment of the present invention, wherein the byproducts thus produced include NaOH and alumina.

Yet another embodiment of the present invention, wherein the purity of the hydrogen thus produced is 99.99% purity, which can be fed directly for usage in fuel cell or in IC engines.

30 Further embodiment of the present invention, wherein the reaction of metal hydride takes place at room temperature and pressure.

The present invention also provides an encapsulated metal hydride shells, said encapsulated metal hydrides comprising;

- (a) a metal hydride core;
- (b) an encapsulated brittle and impermeable polymeric material; and
- (c) sealed encapsulated metal hydride;

An embodiment of the present invention, wherein the metal content for metal
5 hydride is selected from the alkali metals selected include Sodium, Boron, Lithium,
Potassium and magnesium.

Another embodiment of the present invention, wherein the alkaline earth metal
is Calcium.

10 Yet another embodiment of the present invention, wherein the alkali hydrides
are selected from Sodium Hydride, Boron Hydride and Lithium Hydride, and
preferably Sodium Hydride.

Further embodiment of the present invention, wherein the mixed metal hydrides
are selected from Lithium Aluminum Hydride and Sodium Aluminum Hydride and
Sodium Boron Hydride.

15 Yet another embodiment of the present invention, wherein the other Hydrides
are selected from Titanium Iron Hydride (TiFeH), Missmetal Hydride (MhH),
Magnesium Hydride (MgHz) and Magnesium Nickel Hydride (MgNiHz, MgNiH4).

20 Yet another embodiment of the present invention, wherein the metal hydride
shells having shapes selected from spherical, cylindrical, rectangular and square,
preferably spherical.

Further embodiment of the present invention, wherein the encapsulation of
metal hydride shells is done using the polymeric material selected from polystyrene,
poly methyl methacrylate (PMMA), PVC with less plasticizer, HDPE, brittle poly
olefins, preferably polystyrene and PMMA.

25 Yet another embodiment of the present invention, wherein the encapsulated
metal hydride shells are sealed initially with solvents selected from chloroform,
acetone, carbon tetra chloride and alcohol.

Still another embodiment of the present invention, wherein the encapsulated
metal hydride shells are further sealed with instant sealants.

30 Yet another embodiment of the present invention, wherein the encapsulated
metal hydride shells are made in an inert atmospheric pressure using a dye and then
coated with polymeric metals in the desired solvents or with molten brittle polymeric
materials.

A process for the manufacture of encapsulated metal hydride shells, said process comprising;

- (a) preparing the metal hydride palettes;
- (b) coating the palettes with revolving spiral device consisting of molten polymer or a
5 polymer dissolved in a solvent;
- (c) curing a coating to form an impermeable plastic shell;

ADVANTAGES OF THE PRESENT INVENTION

- 1. The system of the present invention provides for an enhanced storage and
10 dispensation of hydrogen at required temperature and pressure conditions.
- 2. In the present invention a single metal hydride system is used for both storage and dispensation of Hydrogen.
- 3. The hydrogen storage is in the form of selected metal hydride in encapsulated and brittle polymeric shells.
- 15 4. The metal hydrides of the present invention are also easy to handle.
- 5. The disintegrated pieces of the encapsulated metal hydride shells reach the bottom portion of the container not only to facilitate an upper free zone of the container for Hydrogen occupation but also for the easy removal of disintegrated pieces from the bottom portion of the container.
- 20 6. The hydrogen gas thus produced has applications in Automobile industry, Metrological applications, power systems in isolated locations, where the systems are not connected to the grid, generation of power with negligible noise, hydrogenation of oils and organic reactions wherever the hydrogen is required.
- 7. Dispensing of hydrogen at desired pressure and flow rate is made feasible.

25

Claims

1. A system for the production, storage and dispensation of hydrogen, said system comprising:
 - (a) at least a sealed and replaceable cylinder filled with water having a lid, mounted vertically on a platform,
 - (b) a rotatable and replaceable container to store encapsulated metal hydride shells, said container is fixed to the inner surface of the cylinder, on both the sides, by supporting rings with rollers to provide a rotatable support,
 - (c) a lid having a moist separation mesh serving as a passage for the hydrogen flow, fixed on top of the cylinder as inlet means for encapsulated metal hydride shells and water before said cylinder is sealed and mounted on the platform,
 - (d) a slider base member disposed at the bottom end of the cylinder said slider is fixed to the inner surface of the cylinder, on both the sides, by supporting rings,
 - (e) said slider base member acts as a bottom to the container, said slider base having a passage, said passage in flow communication with a slider path to transmit the encapsulated metal hydride shells from the container into the cylinder,
 - (f) a plurality of baffles disposed both inside and outside periphery of said rotatable container, said inner baffles adapted to regulate and direct the flow of the encapsulated metal hydride shells of the container on to the slider path through said passage of the slider base and said outer baffles adapted to rotate the container,
 - (g) a pair of movable ramming means extending plane perpendicular to the pair of containers disposed at the bottom end of the slider path, said ramming means including a disintegrating site to receive the encapsulated metal hydride from the slider and a movable piston for the disintegration and dispersion of broken shells and metal hydride into the cylinder,
 - (h) a motion transmitting element mounted on the ramming means connected to outer baffles to provide a corresponding rotatable action to the container;
 - (i) an outlet disposed on the lid of the cylinder to release the hydrogen thus produced in the cylinder, and
 - (j) a control panel to control the operations of the system.
2. The system as claimed in claim 1, wherein said cylinder consisting of a valve at

the bottom end to control the flow of the water, disintegrated shells along with by-products.

3. The system as claimed in claim 1, wherein the lid of the cylinder is an elevated hollow lid disposed on top of the cylinder consisting of hydrogen outlet and rupture diaphragms.
4. The system as claimed in claim 1, wherein optionally a plurality of cylinders and containers is connected in series for hydrogen production, storage and dispensation.
5. The system as claimed in claim 1, wherein said container is made of material selected from mild steel and stainless steel.
10. The system as claimed in claim 1, wherein the ramming means consisting of a movable piston and a cavity at the end to facilitate the disintegration of encapsulated shells.
15. The system as claimed in claim 7, wherein the metal content for metal hydride is selected from Sodium, Boron, Lithium, Potassium and magnesium with aluminum or any metal hydride capable of releasing hydrogen
20. The system as claimed in claim 7, wherein the encapsulated metal hydride shells having shapes selected from spherical, cylindrical, rectangular and square, preferably spherical.
25. The system as claimed in claim 1, wherein the encapsulation of metal hydrides is done using the polymeric material selected from polystyrene, poly methyl methacrylate (PMMA), PVC with less plasticizer, HDPE, brittle poly olefins, preferably polystyrene and PMMA.
30. The system as claimed in claim 1, said hydraulic power means consisting of a hydraulic pack and the hydraulic cylinders with suitable sealing mechanism to prevent leakage during reciprocating motion of the piston while disintegrating the encapsulated metal hydride shells.
11. The system as claimed in claim 1, said system is designed to enable the swapping of empty containers with filled containers with ease preventing the exposure to the chemicals.
12. The system as claimed in claim 1, wherein the control panel is controlled by devices selected from analogue and digital devices.
13. The system as claimed in claim 1, wherein the bottom outlet of the container

consisting of an outlet valve is sealed and opened only during refilling, to prevent accidental spillage.

14. The system as claimed in claim 1, wherein baffles are used to provide an uninterrupted and selected flow of encapsulated metal hydride materials to the disintegration site.
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15. The system as claimed in claim 1, wherein the ramming means crushes the metal hydride shells into small and tiny debris that are collected at the bottom of the container for easy disposal and recycling.
16. The system as claimed in claim 1, the accumulation of disintegrated pieces of encapsulated metal shells facilitates in creating a space in the container itself for storing and dispensing of hydrogen.
10
17. The system as claimed in claim 1, wherein the ramming means can be directed to crush the encapsulated metal hydride shells in any selected cylinder connected to the system.
- 15
18. The system as claimed in claim 1, wherein the intervening gaps among the encapsulated metal hydride shells in the container are utilized as an additional storage means for the hydrogen gas.
19. The system as claimed in claim 1, wherein the hydraulic power means having a hydraulic seal is placed at the bottom of the system not only to prevent the leakage from the system but also to have a multi-container dispensing system.
20
20. The present invention also provides a method for the production, storage and dispensation of hydrogen by using the system as claimed in claim 1, said method comprising the steps of;
 - (a) mounting the sealed cylinders on the platform filled with a proportionate quantity of water and a container with encapsulated metal hydrides,
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 - (b) directing the encapsulated metal hydride into the ramming means by means of baffles disposed in the container and crushing the desired quantities of encapsulated metal hydride shells to disintegrate into small pieces;
 - (c) dispersing the metal hydride into the water;
 - (d) reacting the metal hydride with water to produce hydrogen;
 - (e) releasing the hydrogen through outlet means provided at the top of the cone and container; and
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- (f) collecting the disintegrated pieces and the byproducts at the bottom of the container.
21. The method as claimed in claim 20, wherein the metal content for metal hydride is selected from Sodium, Boron, Lithium, Potassium and magnesium with an addition aluminum powder, or any metal hydride capable of releasing hydrogen, preferably sodium hydride.
- 5 22. The method as claimed in claim 20, wherein the plurality of cylinders disposed for simultaneous disintegration of enhanced number of encapsulated metal hydrides for the production of hydrogen gas.
- 10 23. The method as claimed in claim 20, wherein the aluminum that is used is powder form is in the range of 5-50% to increase the density of the metal hydride and also to produce more hydrogen per unit volume by reacting with an alkali, preferably sodium.
- 15 24. The method as claimed in claim 20, wherein the byproducts consisting of NaOH and alumina.
25. The method as claimed in claim 20, wherein the exothermic reaction condition of the process provides the desired temperature range for the formation alumina.
26. The method as claimed in claim 20, wherein the reaction of metal hydride takes place under controller pressure and temperature.
- 20 27. The method as claimed in claim 20, wherein both low and high density encapsulated metal hydride shells can be used for production, storage and dispensation of hydrogen gas.

Dated 20th January 2004

25


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Attorney for the Applicant

30 The Controller of Patents,
The Patent Office,
At Chennai

ABSTRACT

A system for production, storage and dispensation of hydrogen gas by metal hydride encapsulation. The present invention further provides a method for production, storage and dispensation of hydrogen gas by using the said system.

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Applicant: RAMAKRISHNA NATARAJAN
Application No: 59/MAS/2003

Sheet 1 of 5

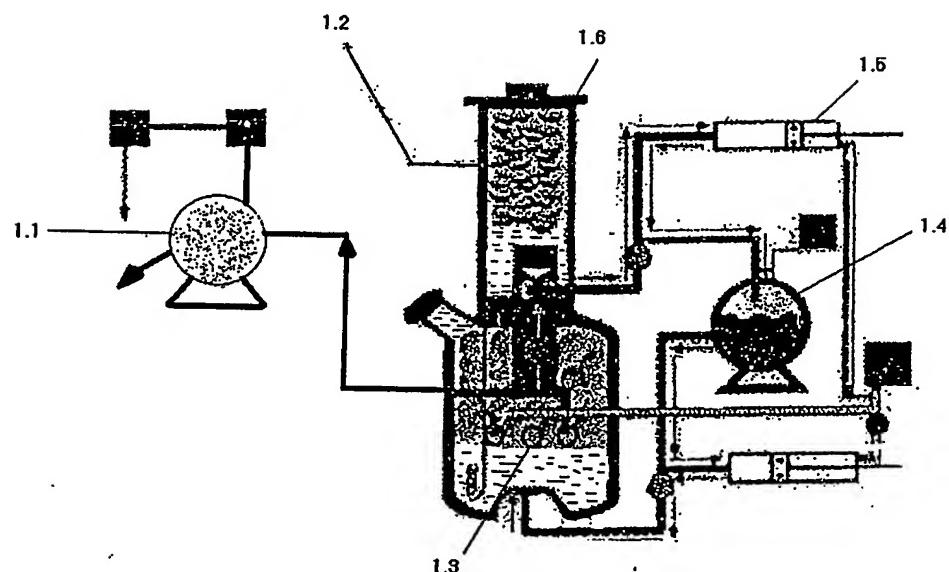


FIG. 1

Applicant: RAMAKRISHNA NATARAJAN
Application No: 59/MAS/2003

Sheet 2 of 5

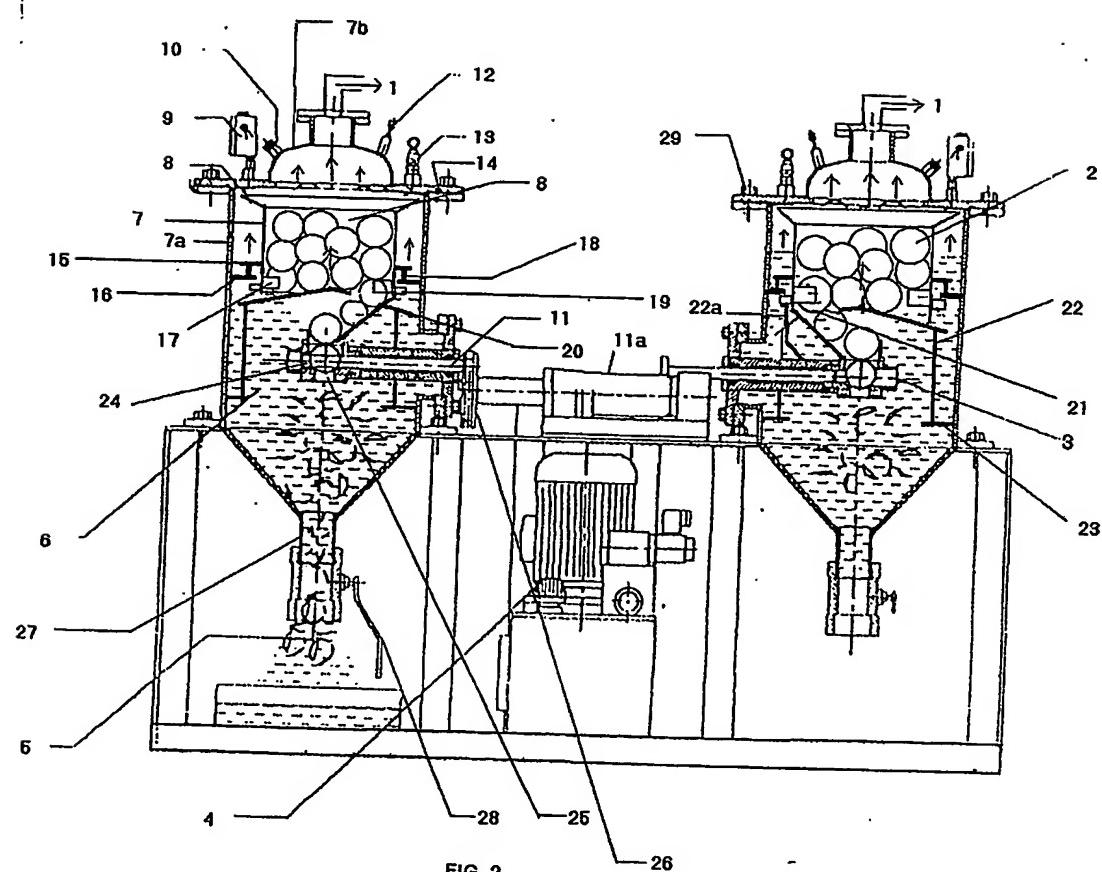


FIG. 2

Applicant: **RAMAKRISHNA NATARAJAN**
Application No: 59/MAS/2003

Sheet 3 of 5

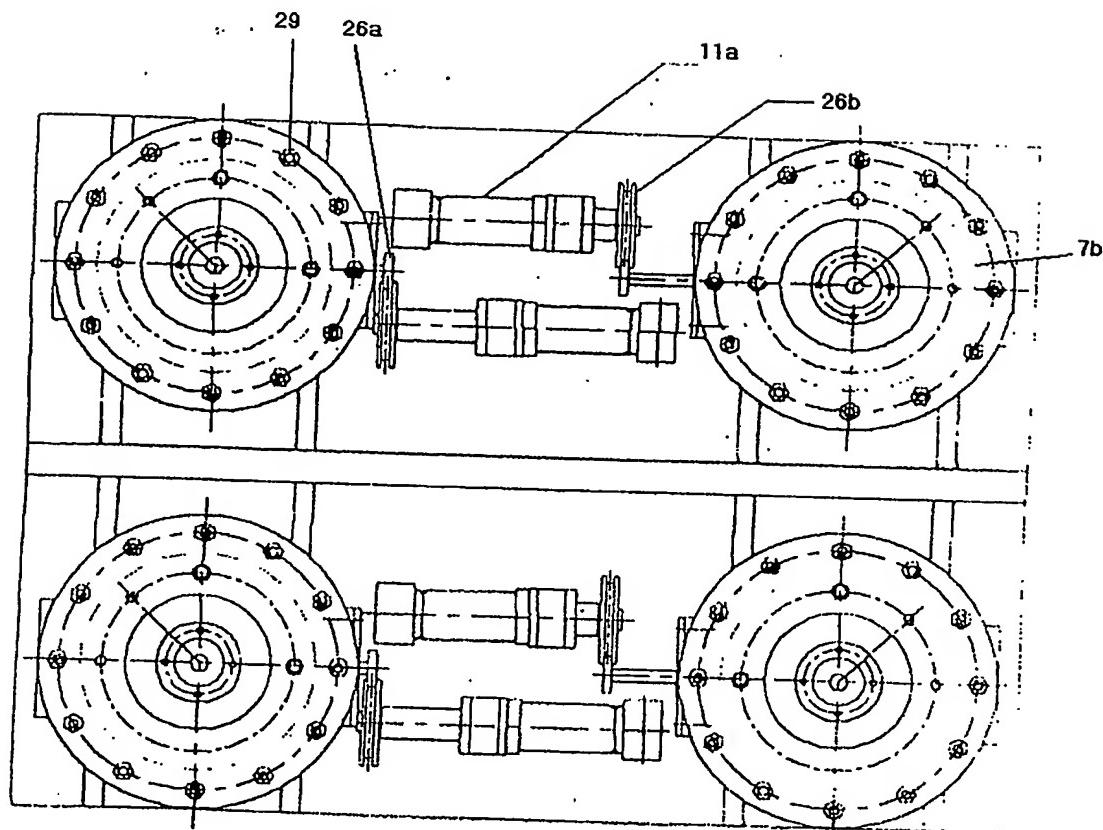


FIG. 3

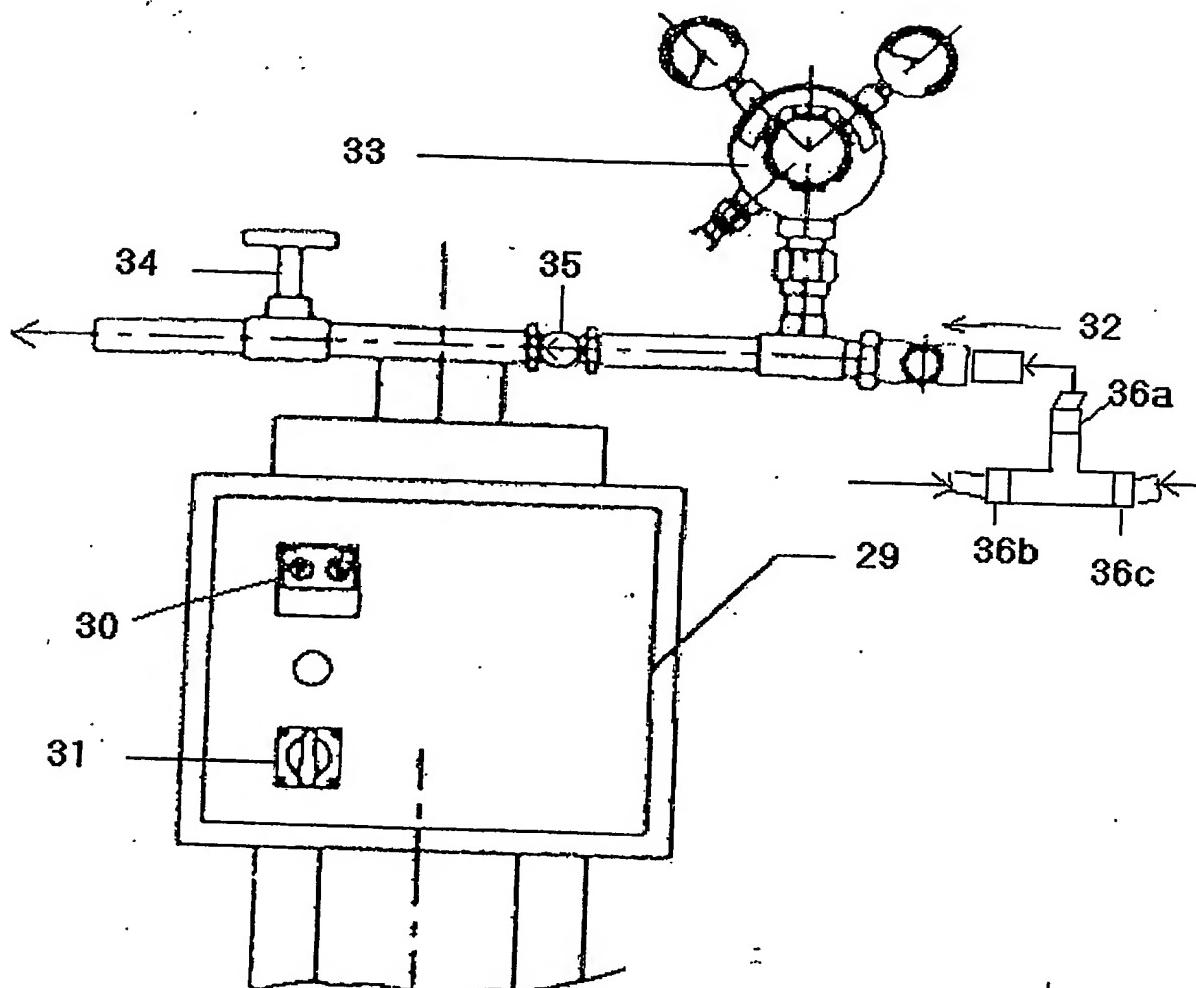


FIG 4

Applicant: RAMAKRISHNA NATARAJAN
Application No: 59/MAS/2003

Sheet 5 of 5

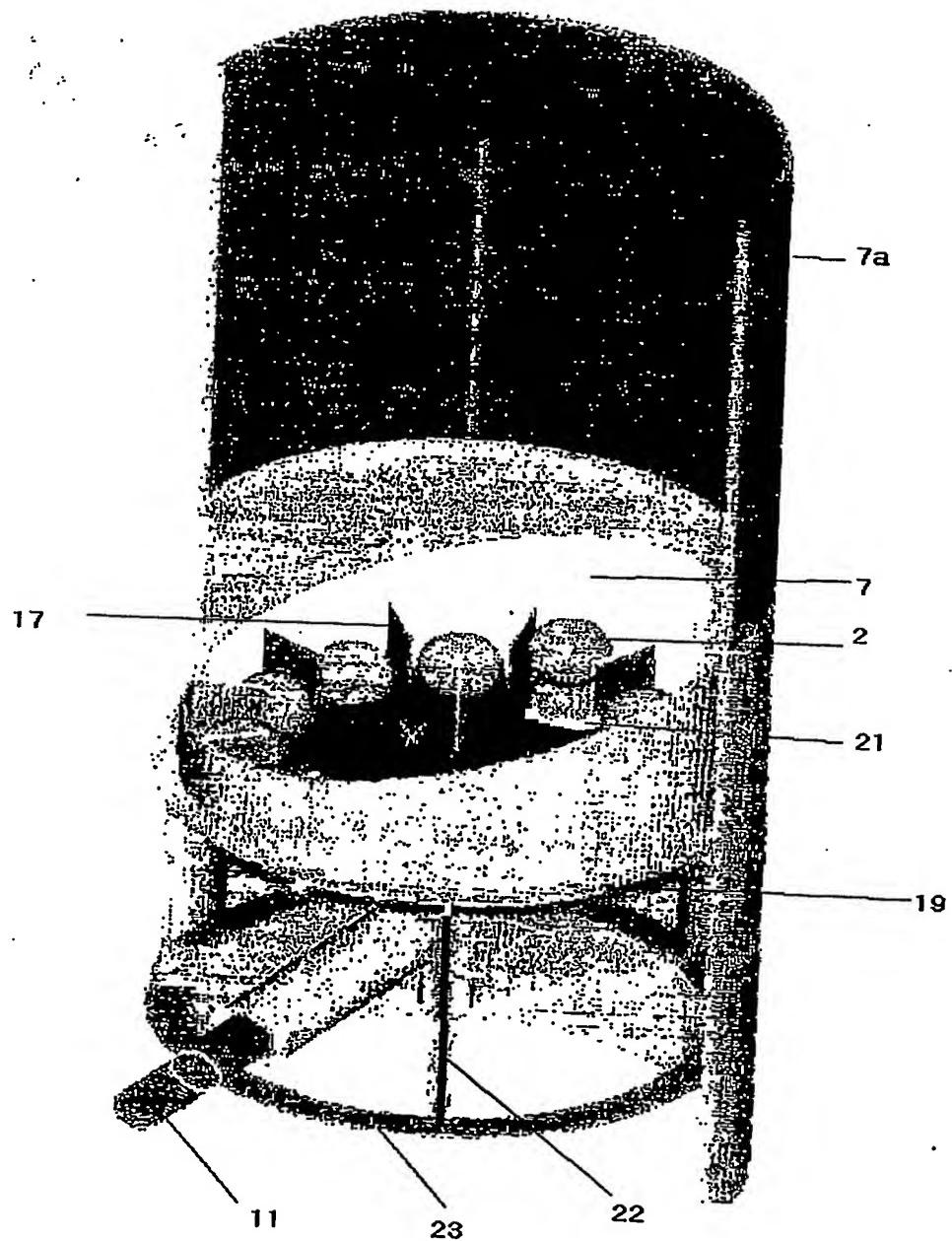


FIG. 5

FORM 2
THE PATENTS ACT, 1970
(39 OF 1970)

PROVISIONAL SPECIFICATION

[See Section 10]

MAS 2003
59

**A SYSTEM AS SINGLE SOURCE FOR STORAGE AND DISPENSATION OF
HYDROGEN WITH METAL HYDRIDE AND A METHOD THEREOF**

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The following specification with diagrams describes the nature of this invention.

ORIGINAL

A SYSTEM AS SINGLE SOURCE FOR STORAGE AND DISPENSATION OF HYDROGEN WITH METAL HYDRIDE AND A METHOD THEREOF

FIELD OF INVENTION

The present invention relates to a modular system as a source for an enhanced storage and dispensation of Hydrogen gas by metal hydride encapsulation. The present invention also relates to an encapsulated metal hydride with a shell for hydrogen storage. The present invention further relates to a process for the storage and dispensation of Hydrogen gas by using the said system.

BACKGROUND AND PRIOR ART

Hydrogen is stored conventionally as a gas or liquid. Hydrogen, due to its very low density, it is stored at very high pressures (more than 3000 psi) or as liquid hydrogen at a very low temperature of -253 °C.

To increase the storage density of hydrogen the application of metal hydride is adopted as an alternative method.

The alkali metals and alkaline earth metals and also some of their hydrides and mixed metal hydrides are also used to generate Hydrogen on reaction with water.

Sodium Hydride is an inexpensive metal hydride that is produced in bulk and hence generally preferred for the storage of hydrogen.

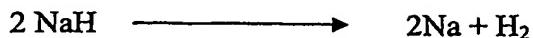
The following are the some of the advantages of storing hydrogen in metal hydrides:

- (a) eliminates high pressure and cryogenic temperature storage,
- (b) eliminates carbon emission observed in reforming of Methane and Methanol,
- (c) production of the desired quantity of hydrogen only when required, and
- (d) recycling of metal hydroxide to produce metal hydride

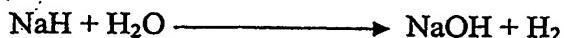
The hydrogen from metal hydride is produced either by heating metal hydride to above 400 °C or by reacting the metal hydride with water.

In heating process, the metal hydrides are extruded as rods, and are decomposed by heating them by means of electrical heaters or flue gas. The temperature for

decomposition is usually at about 400°C . The hydrogen is absorbed over the alkaline metal at high pressure and temperature.



The other alternate method of producing hydrogen is by reacting the metal hydride with water.



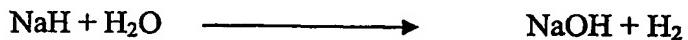
In the case of reaction by decomposition the amount of hydrogen produced is about 50% less when compared with the reaction of metal hydride with water.

Metal hydride decomposition system in automobiles

The requirement of pure hydrogen being a fundamental requirement in fuel cells or IC engines, the metal hydride rods have to be indirectly heated either by an electrical heater or by a flue gas. A separate energy source has to be provided for heating the metal hydrides, resulting in the occupation of more space in the automobile. Another limitation in the process is that factors pertaining to the production and absorption of Hydrogen vary during each recycling, since the metal hydride lattice starts cracking.

Power Ball Technology

Power Ball Technology is one such process, wherein it adopts the following reaction in a reactor:



Power Ball technology is one such process, wherein the sodium hydride in the form of a ball having lesser density than water floats up and the plastic ball is cut into two pieces at the topside of the reactor to enable the sodium hydride to react with water to produce hydrogen.

However, the limitation of this process is that if the metal hydride thus used is heavier than water, in such an event a separate reactor is required for high density metal hydrides. In the above-stated process, the metal hydrides are first formed into a spherical ball of about ping pong ball size and coated with flexible polyethylene jacket made of the following polymeric materials, polyethylene, polypropylene, Kraton, SBR, Noryl, Peek.

Limitations encountered in the conventional water treatment processes are:

- (a) In an upside down reactor system, dispensing of the metal hydride ball cannot be adopted, if the metal hydride balls are heavier than water.
- (b) Mixed metal hydrides like NaAlH that are adopted in the conventional processes are not readily available. By manufacturing NaAlH exclusively for metal hydride project to generate Hydrogen makes the process an expensive one.
- (c) Flexible polyethylene balls that are used to store metal hydrides, conventionally, do not open out but only get crushed, which may result in the malfunctioning of the dispensing system.
- (d) A separate hydrogen storage tank, that is adopted in reactor system, along with dispensing unit, results in duplication of safety and control systems in addition to the addition of other components.

Accordingly, in view of the above limitations, in the present invention, spherical ball flow dynamics and disintegration of low density materials have been studied. During the studies, it is observed that the conventional flexible plastic balls can be opened only when they are sliced into two pieces with sharp chisel like object. It is also further observed that when the brittle plastic balls are used for storing the metal hydrides, they disintegrate into small and tiny pieces, on impact with objects having blunt surfaces.

OBJECTS OF THE PRESENT INVENTION

In order to overcome the above cited limitations, the primary object of the present invention is to provide a single unified and modular system for storage and dispensation of hydrogen gas.

An object of the present invention is to provide a system that can handle metal hydrides lighter and heavier than water for the production of hydrogen.

Another object of the present invention is to provide a system that can serve both as a hydrogen dispenser and a storage unit in the form of a single system.

Yet another object of the present invention is to provide a system with metal hydride storage the capacity of which can be easily increased by attaching additional storage modules to enable automatic and continuous supply of hydrogen at a required pressure and flow rate.

It is also an object of the present invention to provide an encapsulated metal hydride with a flexible and brittle polymeric shell for hydrogen production and method thereof.

Still another object of the present invention is to provide a process for the storage of hydrogen by using said system.

Yet another object of the present invention is to provide metal hydrides encapsulated in a brittle polymeric shell.

Further object of the present invention is to provide a process for the production of hydrogen by using the said system.

SUMMARY OF THE INVENTION

The present invention provides a modular system as a source for an enhanced storage and dispensation of Hydrogen gas by metal hydride encapsulation. The present invention also provides an encapsulated metal hydride with a shell for hydrogen storage. The present invention further provides a process for storage and dispensation of Hydrogen gas by using the said system.

DETAILED DESCRIPTION OF THE INVENTION

A hydrogen storage and dispensing system, said system comprising:

- (a) at least a container fixed firmly on a platform serving as a reactor cum storage means for water, encapsulated metal hydride shells and hydrogen gas;
- (b) a conical means disposed at the upper region of the container and funneling into the container serving as a conduit to feed, hold and regulate the flow of encapsulated metal hydride shells;

- (c) a modular and elevated hollow means on top of the container, to provide an extra room for the storing of encapsulated metal hydride shells and serving as a lid with rings on either side for sealing the container and the conical means;
- (d) a perforated means at the top periphery of the conical container with moist separation mesh serving as a passage for the hydrogen flow;
- (e) flanges for the lid having 'O' rings to prevent leakage;
- (f) a pressure control means housed on top of the lid;
- (g) a high pressure relieving valve means disposed on the lid to facilitate the release of the high pressure generated in the container;
- (h) an outlet means on the top of the container and funnel to control the flow of hydrogen;
- (i) a rupture diaphragm on the elevated hollow means acting as a safety valve;
- (j) a vent means for N₂/H₂ fill cum flushing line;
- (k) an outlet means disposed on the elevated hollow means serving as conduit for the hydrogen gas;
- (l) a hydrogen dispensing means in flow communication with the outlet means of the elevated hollow means to dispense and control the hydrogen gas generated in the container;
- (m) a regulator means in flow communication with the hydrogen dispensing means to control and regulate the dispensation of hydrogen gas;
- (n) a valve and lock means at the narrowed and straightened passage site of the container to prevent accidental discharge of contents of the container;
- (o) a narrowed and straightened passage site with suitable design at the bottom end of the conical container to permit, control and hold the encapsulated metal hydride shells;
- (p) a ramming means extending from the container is disposed at the narrowed and straightened passage site of the conical container with to and fro motions to disintegrate the encapsulated metal hydride shells;

- (q) a hydraulic power means disposed at the bottom of the system to control the ramming means;
- (r) a hydraulic cylinder in flow communication with the ramming means on one side and with hydraulic pack on the other side to facilitate to and fro horizontal movements;
- (s) an outlet means at the narrowed and straightened passage site of the conical container to flush out the broken pieces of the shells and to control the flow of water from the container; and
- (t) a control panel to control the operations of the system.

An embodiment of the present invention, wherein the said system can handle multiple containers to meet the demand of hydrogen productivity.

Another embodiment of the present invention, wherein said container is made of material selected from mild steel and stainless steel.

Yet another embodiment of the present invention, wherein the inner surface of the container is optionally coated with protective coating material selected from polyethylene, epoxy and polyester.

Still another embodiment of the present invention, wherein the conical container used for feeding and storing the encapsulated metal hydrides is disposed at an angle in the range of 30-80° to get an uninterrupted and selected flow of encapsulated metal hydride materials to the disintegration site.

Further embodiment of the present invention, wherein said system handles both low and high density encapsulated metal hydride shells.

Further embodiment of the present invention, wherein the ramming means having a preferable hollow head on the sides to facilitate the holding of metal hydride shells during crushing.

Still another embodiment of the present invention, wherein the ramming means crushes the metal hydride shells into small and tiny debris that are collected at the bottom of the container for easy disposal and recycling.

Still another embodiment of the present invention, wherein the accumulation of disintegrated pieces of encapsulated metal shells facilitates in creating a space in the container itself for storing and dispensing of hydrogen.

Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells having shapes selected from spherical, cylindrical, rectangular and square, preferably spherical.

Further embodiment of the present invention, wherein the intervening gaps among the encapsulated metal hydride shells are utilized as an additional storage means for the hydrogen gas.

Still another embodiment of the present invention, wherein the encapsulation of metal hydrides is done using the polymeric material selected from polystyrene, poly methyl methacrylate (PMMA), PVC with less plasticizer, HDPE, brittle poly olefins, preferably polystyrene and PMMA.

Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells are sealed initially with solvents selected from chloroform, acetone, carbon teta chloride and alcohol.

Still another embodiment of the present invention, wherein the encapsulated metal hydrides are further sealed with instant sealants.

Further embodiment of the present invention, wherein the hydraulic power means having a hydraulic seal is placed at the bottom of the system not only to prevent the leakage from the system but also to have a multi-container dispensing system.

Further embodiment of the present invention, wherein said system is adapted for manifold containers and the encapsulated metal hydride shells can be disintegrated simultaneously depending on the demand for hydrogen gas.

Yet another embodiment of the present invention, wherein said system is designed to enable the swapping of empty containers with filled containers with ease preventing the exposure to the chemicals.

Yet another embodiment of the present invention, wherein the control panel is controlled by devices selected from analogue and digital devices.

Further embodiment of the present invention, wherein the bottom outlet of the container consisting of an outlet valve is sealed and opened only during refilling, to prevent accidental spillage.

Still another embodiment of the present invention, wherein the hydraulic pack and the hydraulic cylinders are provided with suitable sealing mechanism to prevent leakage during reciprocating motion of the piston while disintegrating the encapsulated metal hydride shells.

Yet another embodiment of the present invention, wherein the hydrogen outlets are provided with non-return valves, pressure control valves and flow control valves.

The present invention also provides a process for the storage and dispensation of hydrogen by using the said system, said process comprising the steps of;

- (a) filling the container with proportionate quantity of water through an inlet means;
- (b) filling the conical means with encapsulated metal hydrides containing aluminum through an inlet means;
- (c) ramming the desired quantities of encapsulated metal hydride shells with a ramming device to disintegrating them into small pieces;
- (d) dispersing the metal hydride into the water;
- (e) reacting the metal hydride with water to produce hydrogen;
- (f) releasing the hydrogen through outlet means provided at the top of the cone and container;
- (g) collecting the disintegrated pieces at the bottom of the container for recycling; and
- (h) collecting the byproducts

Still another embodiment of the present invention, wherein the aluminum that is used is powder form in the range of 5-50% to increase the density of the metal hydride and also to produce more hydrogen per unit volume.

Further embodiment of the present invention, the exothermic reaction condition of the process provides the desired temperature range for the formation alumina.

Still another embodiment of the present invention, wherein the byproducts thus produced include NaOH and alumina.

Yet another embodiment of the present invention, wherein the purity of the hydrogen thus produced is 99.99% purity, which can be fed directly for usage in fuel cell or in IC engines.

Further embodiment of the present invention, wherein the reaction of metal hydride takes place at room temperature and pressure.

The present invention also provides an encapsulated metal hydride shells, said encapsulated metal hydrides comprising;

- (a) a metal hydride core;
- (b) an encapsulated brittle and impermeable polymeric material; and
- (c) sealed encapsulated metal hydride;

An embodiment of the present invention, wherein the metal content for metal hydride is selected from the alkali metals selected include Sodium, Boron, Lithium, Potassium and magnesium.

Another embodiment of the present invention, wherein the alkaline earth metal is Calcium.

Yet another embodiment of the present invention, wherein the alkali hydrides are selected from Sodium Hydride, Boron Hydride and Lithium Hydride, and preferably Sodium Hydride.

Further embodiment of the present invention, wherein the mixed metal hydrides are selected from Lithium Aluminum Hydride and Sodium Aluminum Hydride and Sodium Boron Hydride.

Yet another embodiment of the present invention, wherein the other Hydrides are selected from Titanium Iron Hydride (TiFeH), Missmetal Hydride (MhH), Magnesium Hydride (MgH₂) and Magnesium Nickel Hydride (MgNiH₂, MgNiH₄).

Yet another embodiment of the present invention, wherein the metal hydride shells having shapes selected from spherical, cylindrical, rectangular and square, preferably spherical.

Further embodiment of the present invention, wherein the encapsulation of metal hydride shells is done using the polymeric material selected from polystyrene, poly methyl methacrylate (PMMA), PVC with less plasticizer, HDPE, brittle poly olefins, preferably polystyrene and PMMA.

Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells are sealed initially with solvents selected from chloroform, acetone, carbon tetra chloride and alcohol.

Still another embodiment of the present invention, wherein the encapsulated metal hydride shells are further sealed with instant sealants.

Yet another embodiment of the present invention, wherein the encapsulated metal hydride shells are made in an inert atmospheric pressure using a dye and then coated with polymeric metals in the desired solvents or with molten brittle polymeric materials.

A process for the manufacture of encapsulated metal hydride shells, said process comprising;

- (a) preparing the metal hydride palettes;
- (b) coating the palettes with revolving spiral device consisting of molten polymer or a polymer dissolved in a solvent;
- (c) curing a coating to form an impermeable plastic shell;

BRIEF DESCRIPTION OF THE ACCOMPANIED DIAGRAMS

Fig I depicts the hydrogen regulator with control mechanism for the dispensation of the hydrogen gas.

1 Hydrogen for use

2. Control Panel

Fig II depicts the manifold connectivity of the hydrogen containers.

1. Hydrogen outlet
2. Metal hydride shells
3. Ramming device
4. Hydraulic power mechanism
5. An outlet for NaOH and Broken shell pieces
6. Water
7. Conical container
8. Intervening space for hydrogen gas
9. Pressure control switch
10. Rupture diaphragm
11. Hydrogen outlet
12. Hydrogen fill cum flushing line
13. Pressure relief valve
14. 'O' rings

Fig 3 depicts the an elevation of the system for the production, storage of hydrogen gas by means of encapsulated metal hydride shells.

1. Connectivity of manifold Hydraulic cylinder

Fig 4 depicts the prior art hydrogen generation system with separate hydrogen storage and floating broken pieces of metal hydride shells.

1. An outlet for hydrogen and NaOH.
2. A separate Hydrogen storage device
3. Floating broken metal hydride balls
4. Ramming device
5. Reaction chamber

ADVANTAGES OF THE PRESENT INVENTION

1. An enhanced storage and dispensing of Hydrogen at required temperature and pressure conditions.
2. A single metal hydride system used for storage and dispensation of Hydrogen.
3. The selected metal hydride is stored in an encapsulated and brittle polymeric shells.
4. Metal hydrides of the present invention are also easy to handle while filling with metal hydride.
5. The disintegrated pieces of the encapsulated metal hydride shells reach the bottom portion of the container not only facilitate an upper free zone of the container for Hydrogen occupation but also for the easy removal of disintegrated pieces from the bottom portion of the container.
6. The hydrogen gas thus produced has applications in Automobile industry, Metrological applications, power systems in isolated locations, where the systems are not connected to the grid, generation of power with negligible noise, hydrogenation of oils and organic reactions wherever the hydrogen is required.
7. Dispensing of hydrogen at desired pressure and flow rate is made feasible.



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ABSTRACT

A modular and scalable system as a single source for an enhanced storage and dispensation of Hydrogen gas by metal hydride encapsulation. The present invention also provides an encapsulated metal hydride with a shell for use in hydrogen storage and dispensation. The present invention further relates to a process for storage and dispensation of Hydrogen gas by using the said system.

APPLICANT'S NAME : R.NATARAJAN

NUMBER OF PAGES : 4

APPLICATION NUMBER:

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METAL HYDRIDE SYSTEM FOR
HYDROGEN PRODUCTION & SUPPLY

H₂ REGULATOR

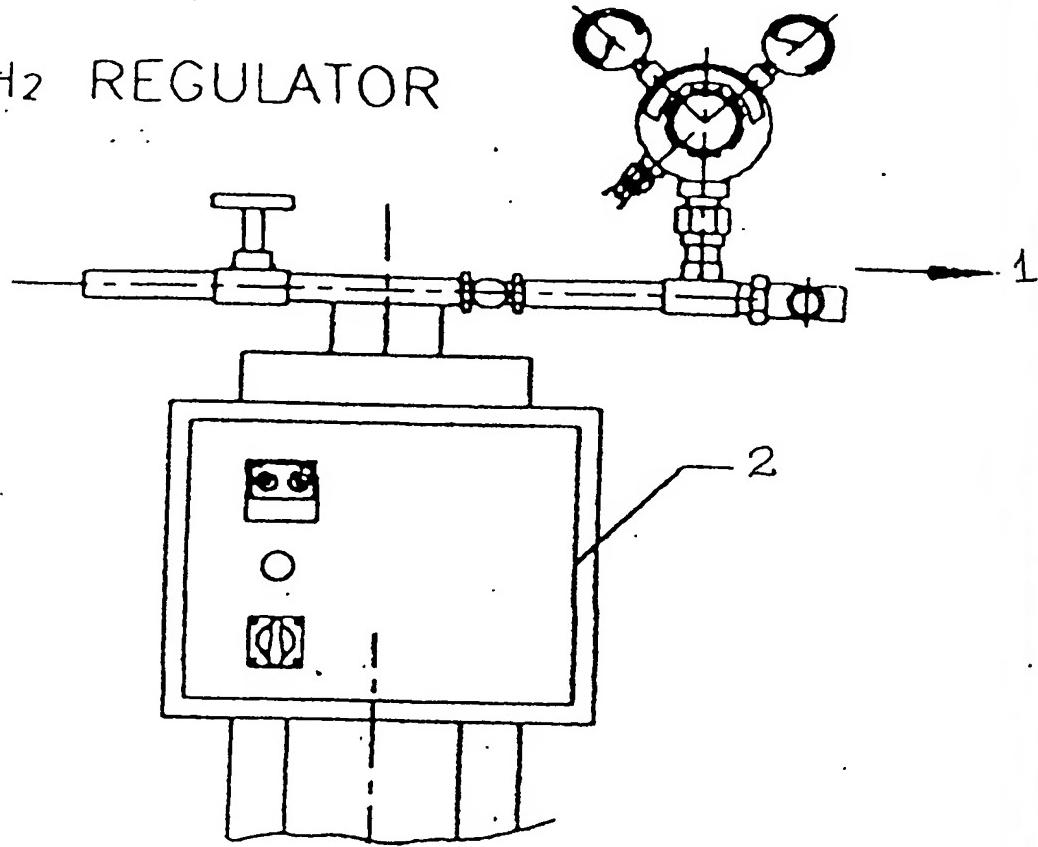


Fig. 1

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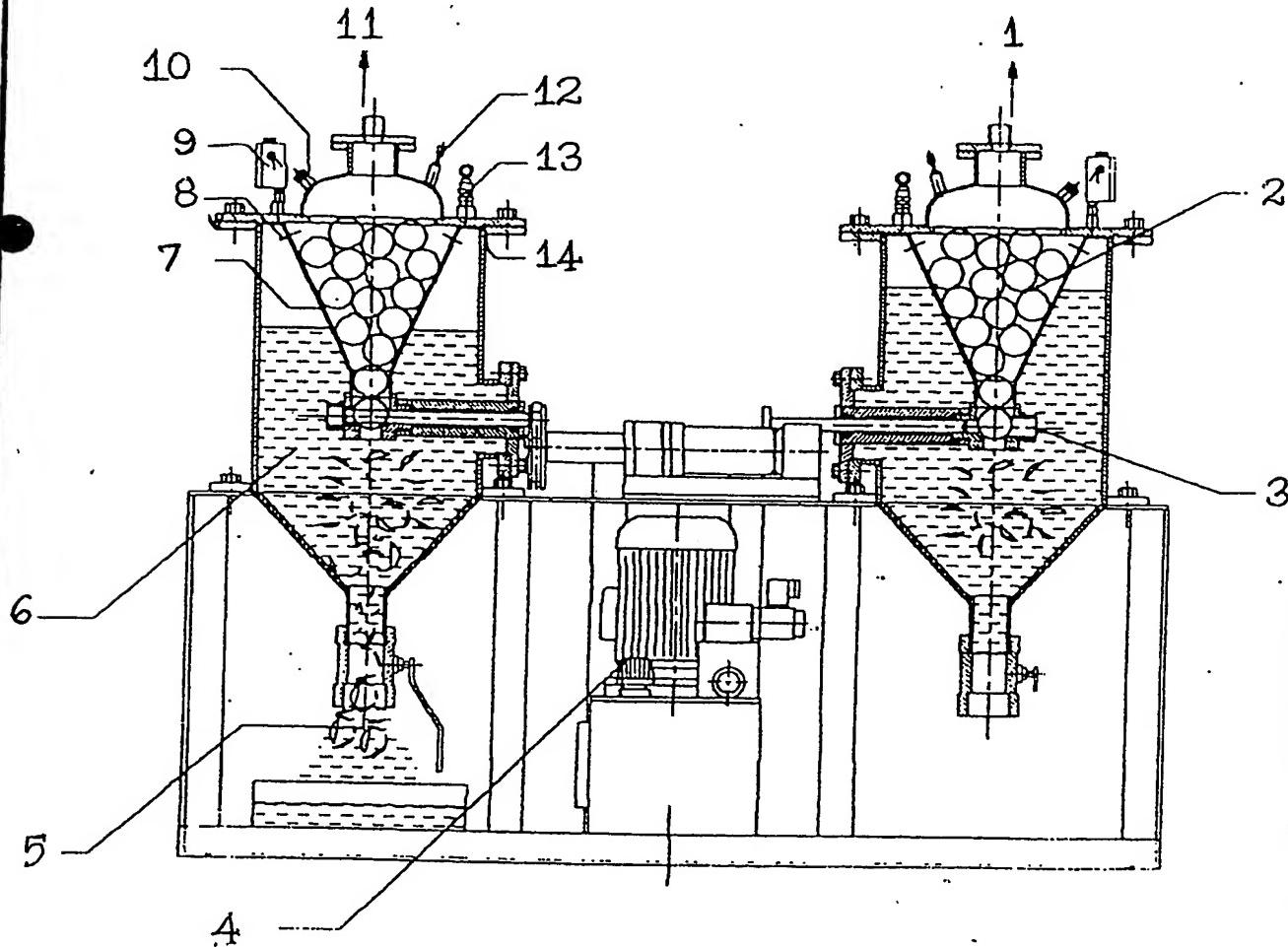


Fig. 2

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METAL HYDRIDE SYSTEM FOR
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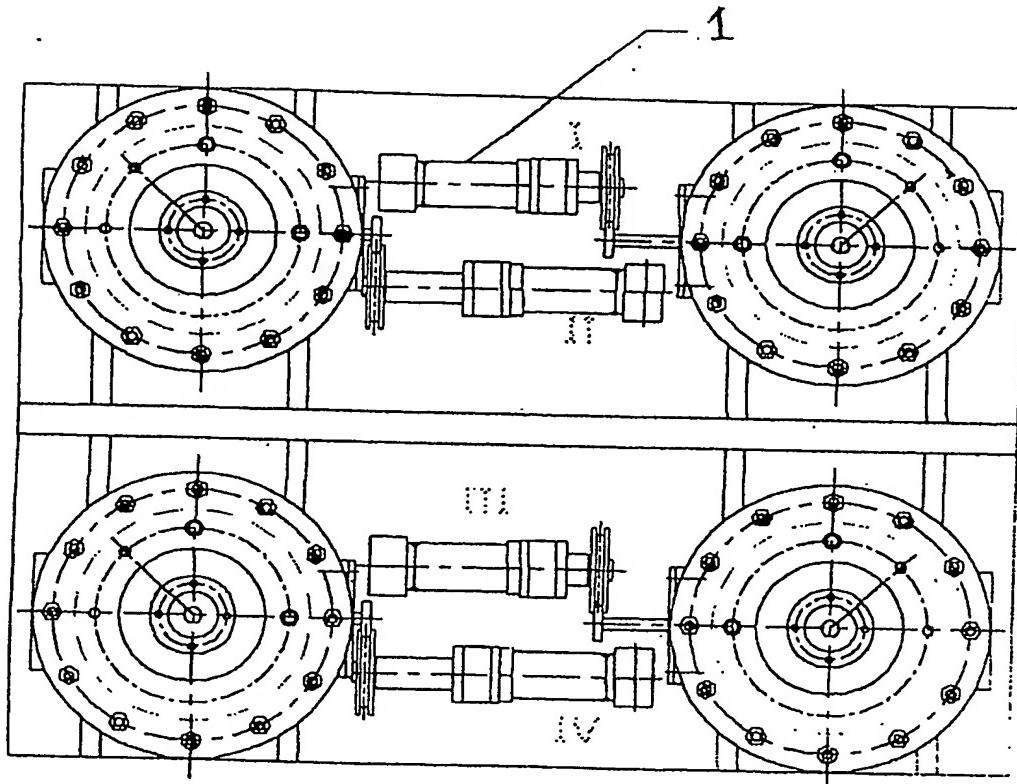


Fig. 3

MULTIPLE CYLINDERS ARRANGEMENT
FOR HYDROGEN SUPPLY

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METAL HYDRYDE SYSTEM FOR
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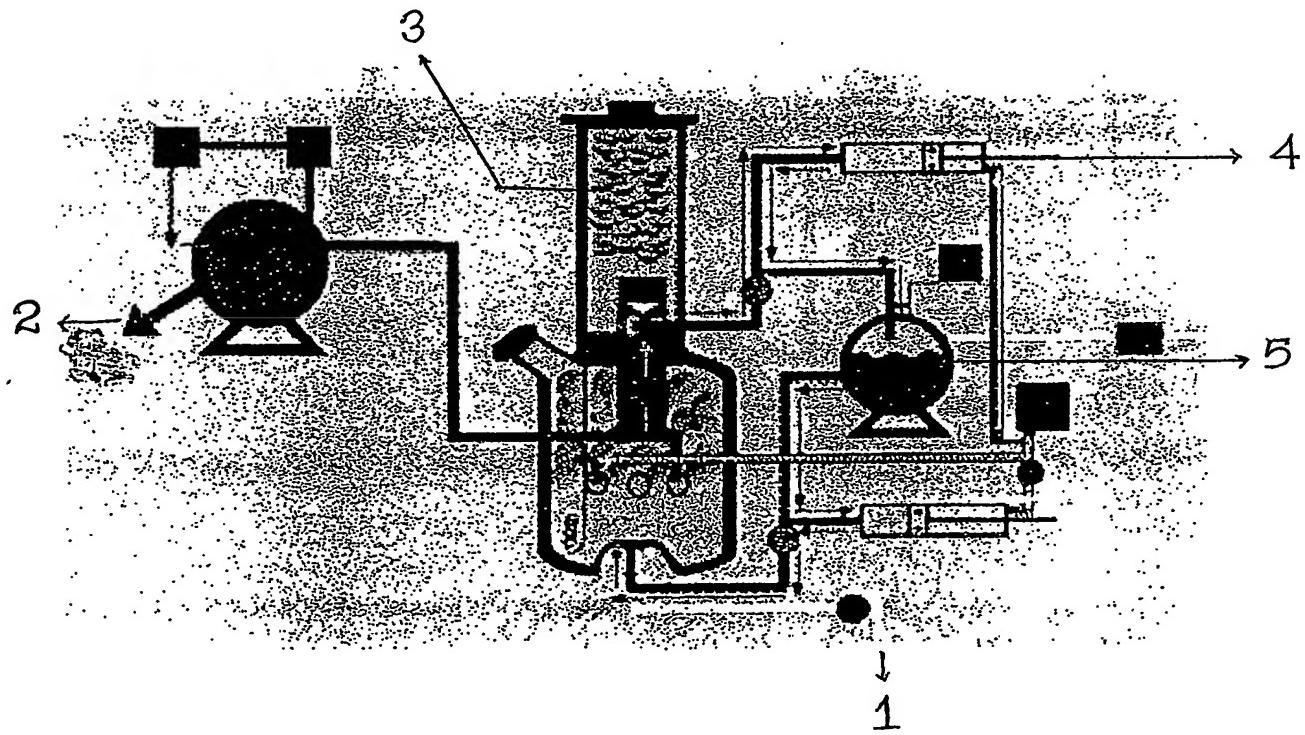


Fig 4

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